A COMPUTERIZED DATA REDUCTION PROGRAM FOR THE CESSNA 310H AIRCRAFT

Alan Walker Yates

NAVAL POSTGRADUATE SCHOOL

Monterey, California

THESIS

A Computerized Data Reduction
Program for the
Cessna 310H Aircraft

by

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A Computerized Data Reduction Program
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Cessna 310H Aircraft

by

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Lieutenant, United States Navy
B.S.M.E., University of Hartford, 1967

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requirements for the degree of

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ABSTRACT

The objective of this thesis was to develop a computer program for use in evaluating data acquired from the Department of Aeronautics Cessna 310H model aircraft. The program was designed for use with the IBM 360 computer, in conjunction with a CALCOMP plotter. The program format is very similar to that of IBM's Scientific Subroutine Package routines; in addition, the program provides the student with a detailed set of instructions for loading the data.

Using information taken from the engine curves for the aircraft, the program evaluates input data, determines the power required for flight at altitude, reduces the values to equivalent sea level values and outputs a graph of power versus velocity for level flight. Lift and drag coefficients are calculated as functions of aircraft weight, velocity, and power required, and are plotted on a second graph.

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I. INTRODUCTION

The laboratory course is one of the most demanding for the graduate student because of the extremely time consuming process of reducing raw data. Often the student may find himself neglecting important course work because of the large amount of work required to reduce laboratory data by hand to meaningful results. This is, of course, an unsatisfactory situation, but is one which seems to be the rule rather than the exception for many students.

The Department of Aeronautics Cessna 310H aircraft flying laboratory, which supports the Flight Evaluation Techniques courses, AE 3321 and AE 3322, at the Naval Postgraduate school, is typical of such time consuming laboratories. With the incorporation of a photo-panel data acquisition system in the aircraft came the capability to collect large amounts of in-flight data which require large amounts of the student's time for evaluation.

There appeared to be a need for some sort of procedure which would reduce the student workload in this laboratory by relieving him of the burden of hand reducing the large volume of raw data and hand plotting the results. A program which would require only that the student assemble the data in a proper sequence and input it to a computer, which in turn would evaluate the data and output tabular and graphical displays of the results, would be extremely beneficial in lightening the student workload. Such a program would free

the student, enabling him to spend time evaluating his results instead of tabulating them. With this need in mind a computer program for the reduction of in-flight data for the Cessna 310H aircraft was written.

CESSNA was designed as a student aid, with the intent that it be self-explanatory, containing all information and instructions necessary for the student to run the program. Parts II and III of this thesis may be used as a user's manual in the event more detailed information is required, or if modification and/or additions are desired. The program is written in FORTRAN language but knowledge of the language is not required, other than the ability to type data cards and a job card in proper format; this format information is readily available at the computer center. The card deck is complete. The student needs only to add his data cards to the end of the deck and it is ready to run.

II. PROGRAM ORGANIZATION AND OPERATION

A. GENERAL ORGANIZATION

As shown in Fig. 1, the complete program consists of two primary sections and two subroutines:

1. Aircraft Power Requirements:
2. Lift and Drag:
3. Interpolation Subroutine:
4. Sorting Subroutine.

When program execution begins, aircraft engine data are read in for internal use in the program. Following this, student data concerning aircraft weight, altitude, velocity, RPM and manifold pressure, and temperature, are read in for evaluation.

CESSNA uses the engine data and the student's RPM and manifold pressure data to determine shaft horsepower required for level flight at the operating altitude for the input velocity range. Horsepower, along with velocity and weight, is then used to determine lift and drag coefficients for the aircraft. Results are printed out in tabular form and are graphed using a CALCOMP plotter.

B. AIRCRAFT POWER REQUIREMENTS

The heart of the program is the set of engine performance curves shown in Fig. 2. On the sea level side of the chart the curves are a linearized version of the original curves (Continental Motors Corporation, 1958), and are a

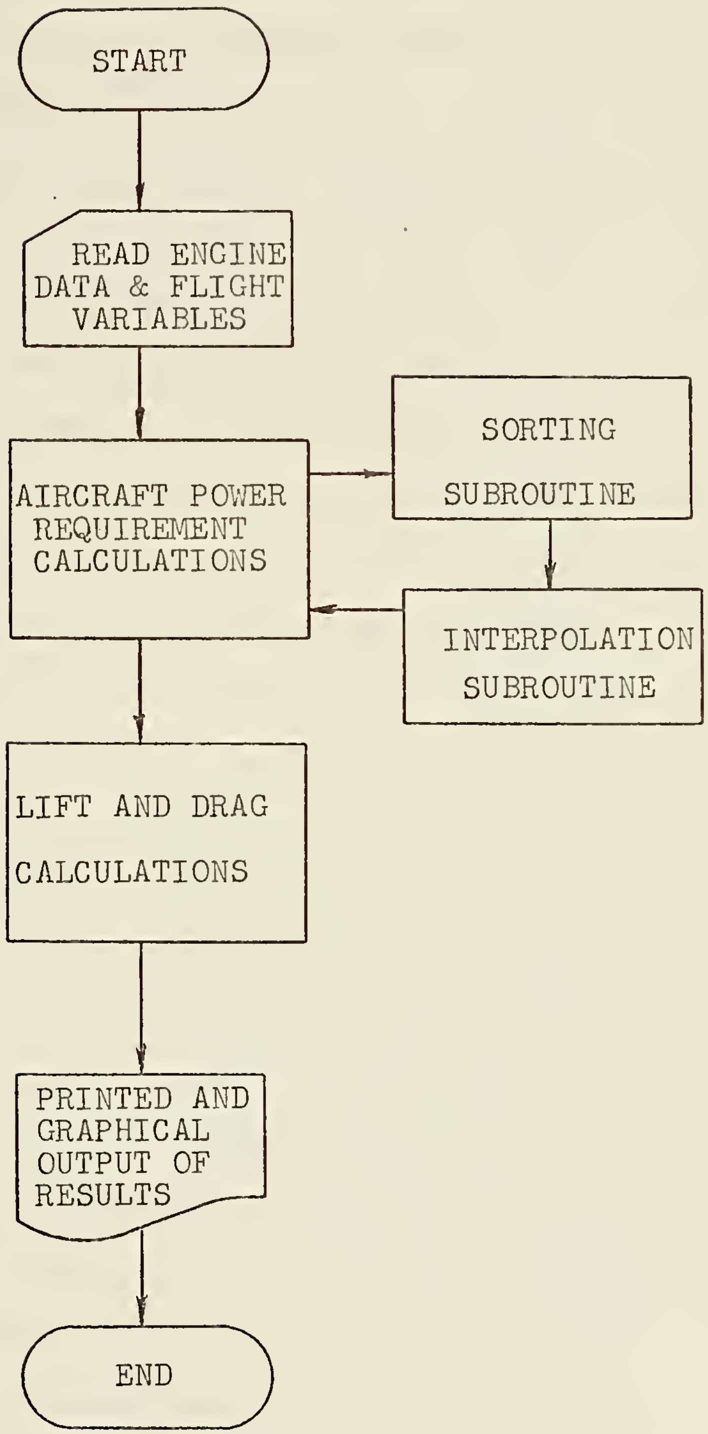


Figure 1

General Program Flow Chart

good approximation to the originals. In the recommended cruising range the maximum error in the linearized curves is approximately 1 to 1.5% in the mid-range RPM's and manifold pressures (or a maximum of approximately 2.5 brake horsepower), and much lower in the upper and lower ranges, where the original curves are very nearly linear. The altitude curves are a copy of the original curves.

The curves are utilized in the following manner. For each RPM line in the sea level set of curves, the slope of the line, maximum manifold pressure, and maximum brake horsepower have been determined. For the altitude set of curves each RPM line has had slope and maximum brake horsepower determined. A question may arise at this point as to why, for a given RPM, the maximum brake horsepower is not the same for both curves and why, therefore, one horsepower value is not sufficient for any calculations needed. The answer is two-fold. First, in linearizing the sea level set of curves, the maximum points for the curves changed, whereas the maximum points for the altitude side did not; hence, two values. Secondly, since points on the RPM lines are determined using slopes and maximum points, it is necessary to keep both values so that calculations for both sets of curves will be accurate.

A simplifying assumption was made concerning the manifold pressure lines on the altitude side. For purposes of this program the lines were assumed to be vertical. This introduces an error of not more than 1.1%, which yields at most a difference of two brake horsepower. This assumption

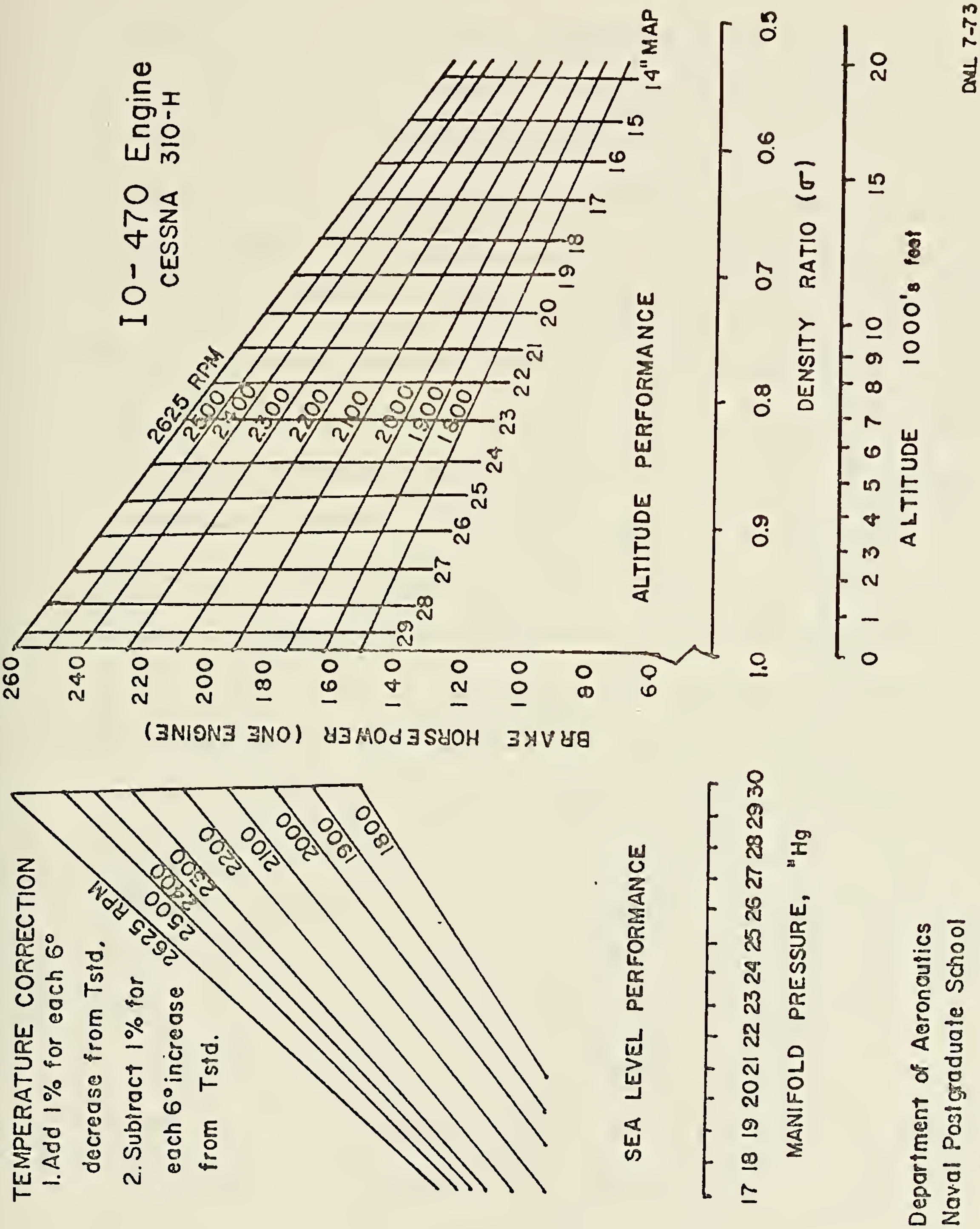


Figure 2

ENGINE PERFORMANCE CURVES

greatly simplifies the method by which manifold pressure is accounted for. Since the altitude curves are graphed as a linear function of the density ratio, a simple conversion is made from manifold pressure to density ratio and this converted ratio (called MAPSIG) is used for calculations, as will be shown later. Table I shows the data used for the MAPSIG conversion. This is a purely mathematical manipulation, used for simplifying the equations by restating one variable in terms of another. This converted ratio is related to the critical operating altitude and is therefore differentiated from the true density ratio (SIGMA) for the actual operating altitude, which is determined in the program from the flight altitude. Table II shows the data used for determining the flight altitude density ratio. Once the engine curve parameters have been determined, power requirements are calculated for a single engine.

On the sea level side, brake horsepower (SSLBHP) is calculated as a function of the maximum brake horsepower (MAXBHP) and maximum manifold pressure (MAXMAP) for the operating RPM, slope of the RPM line (RSLOPE), and operating manifold pressure (MAP) according to the equation:

$$SSLBHP = MAXBHP - RSLOPE\ (MAXMAP - MAP) \tag{1}$$

The procedure for determining a value for brake horsepower at altitude is reasonably straightforward. The critical altitude (BHPCR) for a given manifold pressure is that altitude represented by the intersection of the operating RPM and manifold pressure lines. The converted density ratio (MAPSIG) discussed earlier defines this altitude.

TABLE I

MAPSIG CONVERSION DATA

MAP	MAPSIG	MAP	MAPSIG	MAP	MAPSIG
14.	.545	20.	.730	26.	.905
15.	.580	21.	.760	27.	.935
16.	.615	22.	.790	28.	.965
17.	.640	23.	.820	29.	.990
18.	.675	24.	.855		
19.	.705	25.	.880		

TABLE II

ALTITUDE/DENSITY RATIO CONVERSION DATA

ALT	SIGMA	ALT	SIGMA	ALT	SIGMA
0.	1.00000	6000.	.83586	12000.	.69317
1000.	.97106	7000.	.81064	13000.	.67133
2000.	.94277	8000.	.78601	14000.	.65002
3000.	.91512	9000.	.76196	15000.	.62923
4000.	.88808	10000.	.73848		
5000.	.86167	11000.	.71555		

A straight line is drawn connecting this point with the sea level brake horsepower value. Then a vertical line is drawn upward from the operating density ratio on the abscissa. If this line intersects the SSLBHP-BHPCR line, then that intersection defines the brake horsepower required for level flight at the operating altitude. If the vertical line lies to the right of the critical altitude then its intersection with the operating RPM line defines the required brake horsepower. Figure 3 shows an example of engine curve utilization.

Critical brake horsepower (BHPCR) is calculated as a function of maximum brake horsepower for the operating RPM (MABHP), the slope of the operating RPM line (ARSLOP) and the converted density ratio (MAPSIG) according to the equation:

$$\text{BHPCR} = \text{MABHP} - \text{ARSLOP}\ (1.0 - \text{MAPSIG}) \qquad (2)$$

The slope of the line connecting sea level and critical brake horsepowers (LSLOPE) is also a function of the converted density ratio:

$$\text{LSLOPE} = (\text{BHPCR} - \text{SSLBHP}) \ / \ (1.0 - \text{MAPSIG}) \qquad (3)$$

The operating altitude is compared with the critical altitude. If the operating altitude is the lower one, brake horsepower is calculated on the operating RPM line as:

$$\text{BHPALT} = \text{SSLBHP} + \text{LSLOPE}\ (1.0 - \text{SIGMA}) \qquad (4)$$

If the operating altitude is above the critical altitude then brake horsepower is calculated on the operating RPM line as:

$$\text{BHPALT} = \text{MABHP} - \text{ARSLOP}\ (1.0 - \text{SIGMA}) \qquad (5)$$

It should be noted at this point that the actual flight data are based on thrust horsepower rather than brake horsepower. In the classroom the student takes an ideal brake horsepower, applies the necessary corrections and then multiplies that value by propeller efficiency to get the actual thrust horsepower available. This program does exactly the opposite. From in-flight RPM and manifold pressure it calculates the actual thrust horsepower required. This is corrected, and then converted to shaft horsepower (it is assumed that shaft and brake horsepower are equal) by dividing by propeller efficiency.

Since the engine performance curves are plotted in terms of brake horsepower, the nomenclature of the program up to this point has been written in terms of brake horsepower. However, since the horsepower value just found using equation (5) is actually a thrust horsepower, from here on it will be referred to as a thrust horsepower, until it is converted to shaft horsepower.

Once the basic thrust horsepower value has been determined, several correction factors are applied, the first of which is for temperature variation. The engine curves are plotted for standard temperature; a correction factor

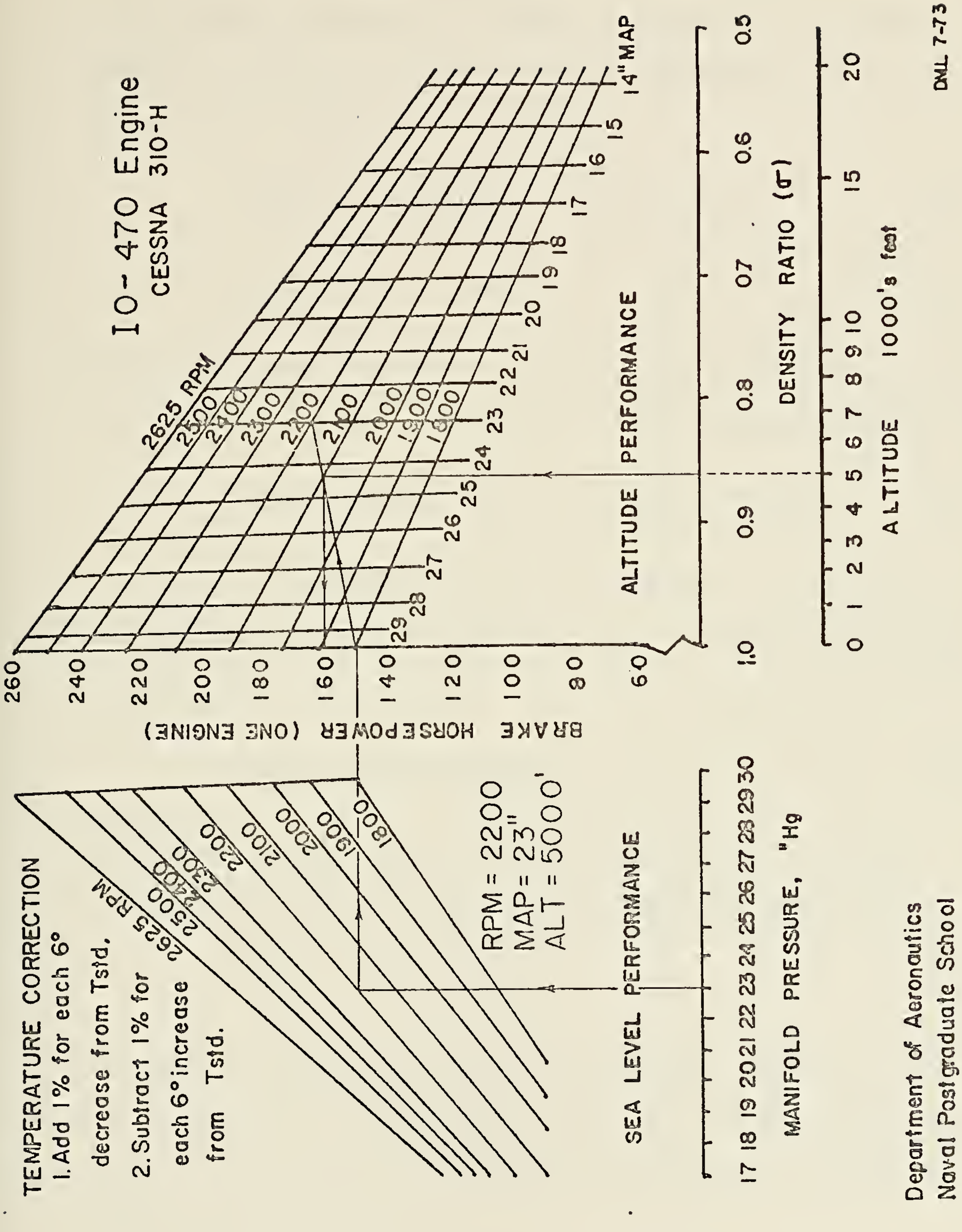


Figure 3

ENGINE CURVE UTILIZATION

is supplied with them. First the temperature is changed from degrees Fahrenheit (TEMPF) to degrees Centigrade (DEGC) and the difference between operating and standard temperatures (TDIF) is determined:

$$DEGC = 5.0\ (TEMPF - 32.0)\ /\ 9.0 \tag{6}$$

$$TDIF = 15.0 - DEGC \tag{7}$$

Then, using the correction factor, the single engine thrust horsepower corrected for temperature variation (CBHP) is:

$$CBHP = BHPALT\ (1.0 - 0.0016667\ (TDIF)) \tag{8}$$

The total thrust horsepower (TBHPA) is found by multiplying the temperature corrected value by the number of engines:

$$TBHPA = CBHP\ (NOENG) \tag{9}$$

Total shaft horsepower required at altitude is found by dividing thrust horsepower by propeller efficiency:

$$TSHPA = TBHPA\ /\ PE \tag{10}$$

Propeller efficiency has been arbitrarily chosen as 0.75 and is entered in the program using a DATA statement for ease of access, should subsequent evaluation dictate a change in the value.

The total shaft horsepower is good for one altitude and one temperature. To make this information more useful

it is converted to an equivalent shaft horsepower (SSLPWR) which may be used to find horsepower at any altitude for the given temperature:

$$\text{SSLPWR} = \text{TSHPA} \quad \sqrt{\text{SIGMA}} \tag{11}$$

The relationship between velocity and power and their equivalent counterparts is most easily shown by the following sequence of equations:

$$q_{ssl} = \tfrac{1}{2} \rho_o V^2$$

and

$$q_{alt} = \tfrac{1}{2} \rho V^2$$

also

$$\sigma = \rho / \rho_o \qquad ; \qquad \rho = \sigma \rho_o$$

so

$$q_{alt} = \tfrac{1}{2} \rho_o \sigma V^2$$

Define equivalent velocity: $V_e = \sqrt{\sigma} \; V$

then

$$q_{alt} = \tfrac{1}{2} \rho_o V_e^2$$

$$P = TV = DV$$

$$= \tfrac{1}{2} S C_d \rho V^2 V = \tfrac{1}{2} S C_d \rho V^3$$

$$= \tfrac{1}{2} S C_d \rho_o \sigma V^3$$

Define equivalent power: $P_e = P \sqrt{\sigma}$

$$P \sqrt{\sigma} = \tfrac{1}{2} S C_d \rho_o \sigma^{\frac{3}{2}} V^3 = \tfrac{1}{2} S C_d \rho_o (\sqrt{\sigma} \; V)^3$$

$$= \tfrac{1}{2} S C_d \rho_o V_e^3$$

Once equivalent power has been calculated, the remaining step in the power requirements section is to change velocity to equivalent velocity (EQVEL):

$$EQVEL = VEL \sqrt{SIGMA} \qquad (12)$$

C. LIFT AND DRAG

Lift is a function of density, velocity, characteristic area and the lift coefficient. In order to avoid the necessity of inputing or calculating a density for the flight altitude, the equations for determining lift and drag coefficients are based on equivalent velocity, reducing density to a constant (sea level value).

$$\text{Lift} = \text{weight} = \tfrac{1}{2} \rho V^2 S C_1$$

$$= \tfrac{1}{2} \rho_o \sigma V^2 S C_1$$

$$= \tfrac{1}{2} \rho_o (\sqrt{\sigma} V)^2 S C_1$$

$$= \tfrac{1}{2} \rho_o V_e^2 S C_1$$

For the calculations, equivalent velocity is changed from knots to feet per second (VEFPS):

$$VEFPS = EQVEL (6000.) / 3600. \qquad (13)$$

Then the lift coefficient (CLIFT) is found as a function of weight (WT) and equivalent velocity:

$$CLIFT = 2 (WT) / (.0023769) (S) (VEFPS)^2 \qquad (14)$$

The characteristic area, S, is defined by a data statement at the beginning of the program for ease of access. There are two values given for S (NASA TN-D-6238, 1971). In this program 200 square feet is used, which includes tip tanks. Without them the wing area is 179 square feet.

Drag is a function of density, velocity, characteristic area and the drag coefficient. It is also a function of velocity and power:

$$\text{Drag} = P / V = P_e / V_e$$

$$= \tfrac{1}{2} \rho V_2 S C_d$$

$$\text{or equivalently, } P_e = \tfrac{1}{2} \rho S C_d V^2 V_e$$

$$= \tfrac{1}{2} \rho_o S C_d V_e^3$$

For the calculations, equivalent power is changed from shaft horsepower to foot-pounds per second (PEFPPS):

$$\text{PEFPPS} = \text{SSLPWR}\ (550.) \qquad (15)$$

Then the drag coefficient (CDRAG) is found as a function of equivalent power and equivalent velocity:

$$\text{CDRAG} = 2\ (\text{PEFPPS}) / (.0023769)\ (\text{VEFPS})^3 \qquad (16)$$

Once all computations have been completed, a table of velocity, manifold pressure, brake horsepower at altitude, equivalent velocity, equivalent shaft horsepower, lift coefficient and drag coefficient is printed out. Then two calls are made to DRAWP, one of IBM's plotting subroutines used in conjunction with a CALCOMP plotter. The first call is for a graph of equivalent power versus equivalent velocity; the second is for a graph of lift coefficient versus drag coefficient.

D. INTERPOLATION SUBROUTINE

As stated earlier, the heart of the program is the data obtained from engine curves for the Cessna. Originally it was decided that these data would be used to formulate

equations with RPM as the independent variable. Then, given an operating RPM, all necessary information could be obtained using the equations, eliminating the need for table searches and interpolation. Several subroutines from IBM's Scientific Subroutine Package, including LSQPL2, CHBFT, and SPLIN, were utilized in an effort to formulate equations which would accurately represent the engine data. However, due to problems with convergence, extended precision requirements for curve coefficients, and decreasing accuracy with increasing curve order, all of these routines proved unsatisfactory in producing the required equations. It was therefore decided to write a simple subroutine which would interpolate in a table of data from the engine curves.

Subroutine LINT performs linear interpolation or extrapolation. Inputs to the subroutine are two columns of data and an independent variable for which LINT will interpolate the dependent variable. The data column corresponding to the independent variable must be in monotonically increasing order but may be arbitrarily spaced. Since the engine curves are for a single engine, flight with two engines allows operation of each engine at values below those shown on the engine performance curves, but not above. Subroutine LINT was therefore written to extrapolate below the limits of the curves but not above. In the event that the independent variable falls above the range of data given, an error message so stating this is printed out.

The method used by LINT is very simple. First a check is made to see if the variable is below the range for interpolation; if this is so, an extrapolation is performed. Otherwise the column is searched until bracketing values are found, at which time an interpolation is performed. If a bracketing pair cannot be found, the variable is above the data range and the error message is printed.

E. SORTING SUBROUTINE

To make the program easier to use, it was written so that the student's data may be loaded in any order. It is not necessary, for example, to put the data in order of increasing velocity. Subroutine SORT does this ordering during program execution so that the printed output data is ordered in terms of increasing velocity. SORT is written to evaluate one column of data, and to put two associated columns of data in the same chronological order as the one being evaluated.

The method used by SORT is simple. A logical flag is set equal to FALSE. Then sequential pairs of values in the first data column are compared. If the second value in any one of these pairs is less than the first value in the pair, the positions of the two values, and of the associated values in the other two columns, are switched and the logical flag is set equal to TRUE. When the entire column has been searched, the flag is checked; if it has been reset (to TRUE), this indicates the possibility that there may be more switches necessary

so the flag is reset to FALSE and the procedure is repeated. When a complete column search is made without resetting the flag, the data are in proper order and control returns to the main program. Like the main program, the subroutine is limited to 100 data points per column.

III. PROGRAM USAGE

A. DATA LOADING

The first data to be loaded following execution of the program are the engine data, consisting of the slope, maximum manifold pressure and maximum brake horsepower (again, brake horsepower values are used here because the engine data comes from curves which are plotted in terms of brake horsepower) for sea level performance, and slope and maximum brake horsepower for altitude performance, for each of nine sets of RPM lines. These data are shown in Table III. Following the permanent data are the student's in-flight data.

The order in which in-flight data is loaded varies. The program gives the option of constant or variable RPM, and the input order depends on which option is selected. To simplify the student data loading, input data formats for both options are included in the program. These formats are similar to those used by James Melsa in his book of computer programs for linear control theory. They give card by card instructions for loading the data, including card number, column numbers, data description, and input

TABLE III

ENGINE PERFORMANCE DATA

RPM	RSLOPE (BHP/INCH)	MAXMAP (INCHES HG)	MAXBHP (HP)	ARSLOP (BHP/INCH)	MABHP (HP)
1800	6.45	29.75	150.0	173.91	150.0
1900	7.16	29.70	164.5	186.67	163.0
2000	7.37	29.65	175.0	200.00	175.0
2100	8.17	29.60	193.0	216.67	191.0
2200	8.72	29.55	208.5	235.16	207.5
2300	9.24	29.50	223.5	254.94	223.5
2400	10.00	29.40	239.0	267.03	237.5
2500	10.56	29.40	248.0	281.32	249.0
2625	11.09	29.35	260.0	294.50	260.0

TABLE IV

EXAMPLE PROBLEM DATA

RPM	MAP (INCHES HG)	VEL (KNOTS)	RPM	MAP (INCHES HG)	VEL (KNOTS)
2100	17.5	85.0	2450	20.0	151.5
2100	19.0	100.0	2300	18.0	135.0
2100	19.75	115.0	2100	18.0	119.5
2100	20.8	130.0	2100	18.0	108.0
2200	22.0	145.0	2100	15.0	87.5
2300	23.6	160.0	2100	16.0	80.0
2300	23.6	160.0	2100	18.0	89.0
2200	22.0	145.0	2100	18.5	111.5
2100	20.1	130.0	2100	19.0	122.0
2100	19.2	115.0	2100	21.0	130.5
2100	18.6	100.0	2300	21.5	144.5
2100	17.5	85.0	2300	23.0	152.5
2450	23.0	164.0	2300	24.0	158.5

format. These formats are presented in the program in Appendix A.

Following the input of constant flight parameters, such as altitude and weight, velocities and manifold pressures are read in. If RPM is variable, its values are read in; otherwise the constant RPM value is read in and duplicated for each set of velocity and pressure. This duplication is done for use in the sorting subroutine, which requires a column of RPM data, and for the printed output, which includes a column for RPM. Once all the data are read in and sorted, the engine curve performance parameters are interpolated for each RPM, if RPM is variable; if it is constant the parameters are evaluated only once, saving unnecessary computer time. Following this evaluation, the power, lift and drag requirements are calculated.

B. GRAPHICAL OUTPUT

The power requirements and lift and drag coefficients for the aircraft are graphed on the CALCOMP plotter, using IBM's DRAWP subroutine. Each graph is eight inches by ten inches, with a title below. The abscissa and ordinate are automatically scaled by the subroutine and the scale information is printed below the graph. Data points are plotted on the graph as triangles. This was done for several reasons. If the subroutine is instructed to plot a continuous curve, it merely connects each point to the next with a straight line. This will produce a very

erratic curve in the case of data with any degree of spread, and where there are only a few data points to plot. The use of triangles allows the student to draw a smooth curve through the data. It also allows the data to be loaded in any order, rather than forcing the student, for example, to arrange his data in increasing order. This last point is admittedly academic, since addition of the sorting subroutine eliminates any plotting problems which might have occurred from unordered data.

IV. EXAMPLE PROBLEM

Two actual sets of student data were combined for the example problem. RPM was variable. Table IV shows the RPM values and associated manifold pressures and velocities. Temperature varied slightly during the test flights; an average value was calculated for use in the program. Aircraft and flight parameters are shown in Table V. The order of the data deck is shown in Appendix B.

Results of the program compared very favorably with hand calculated data. Table VI shows the tabulated output from the program. There was some spread in the data, which is easily visible in the sample graphical output shown in Appendix C.

TABLE V

EXAMPLE PROBLEM - AIRCRAFT FLIGHT PARAMETERS

Number of engines operating: 2

Flight altitude (feet): 5000

Temperature (degrees F): 76.55

Aircraft weight (pounds): 4500

Number of data points: 26

TABLE VI

SAMPLE PROBLEM TABULATED RESULTS

I	VEL (I)	RPM(I)	MAP(I)	BHPALT(I)	EQVEL(I)	SSLPWR(I)	CLIFT(I)	CDRAG(I)
1	80.0	2100.	16.0	91.1	74.3	221.9	1.236	0.271
2	85.0	2100.	17.5	103.3	78.9	251.5	1.095	0.256
3	85.0	2100.	17.5	103.3	78.9	251.5	1.095	0.256
4	87.5	2100.	15.0	82.4	81.2	200.6	1.033	0.187
5	89.0	2100.	18.0	107.7	82.6	262.4	0.999	0.233
6	100.0	2100.	19.0	116.1	92.8	282.7	0.791	0.177
7	100.0	2100.	18.6	112.8	92.8	274.6	0.791	0.172
8	108.0	2100.	18.0	107.7	100.3	262.4	0.678	0.130
9	111.5	2100.	18.5	111.9	103.5	272.5	0.636	0.123
10	115.0	2100.	19.8	121.8	106.8	296.7	0.598	0.122
11	115.0	2100.	19.2	117.6	106.8	286.5	0.598	0.118
12	119.5	2100.	18.0	107.7	110.9	262.4	0.554	0.096
13	122.0	2100.	19.0	116.1	113.2	282.7	0.531	0.097
14	130.0	2100.	20.8	130.4	120.7	317.6	0.468	0.090
15	130.0	2100.	20.1	124.6	120.7	303.4	0.468	0.086
16	130.5	2100.	21.0	132.1	121.1	321.7	0.464	0.090
17	135.0	2300.	18.0	127.2	125.3	309.8	0.434	0.079
18	144.5	2300.	21.5	159.8	134.1	389.0	0.379	0.081
19	145.0	2200.	22.0	152.8	134.6	372.2	0.376	0.076
20	145.0	2200.	22.0	152.8	134.6	372.2	0.376	0.076
21	151.5	2450.	20.0	158.3	140.6	385.5	0.345	0.069
22	152.5	2300.	23.0	174.3	141.6	424.5	0.340	0.075
23	158.5	2300.	24.0	185.9	147.1	452.7	0.315	0.071
24	160.0	2300.	23.6	181.1	148.5	441.1	0.309	0.067
25	160.0	2300.	23.6	181.1	148.5	441.1	0.309	0.067
26	164.0	2450.	23.0	190.2	152.2	463.0	0.294	0.066

V. PROJECT EVALUATION

It is felt that the program has met the objectives previously set forth. A simple, easy-to-use program has been written which evaluates aircraft in-flight data and produces graphs of power versus velocity, and lift coefficient versus drag coefficient. It yields results which are comparable in accuracy to results calculated by hand. Additionally, there is a considerable savings in man-hours required by the student to evaluate his data, which was the original impetus for this thesis.

VI. AREAS FOR PROGRAM EXPANSION

There are several possibilities for future expansion of the program. Temperature variation, though small, may have a noticeable effect on performance figures, and a program option allowing variable temperatures would be beneficial. The same is true for an option which would allow altitude to vary. Test flights are subject to weather, and clouds, for example, do not always allow a flight to be performed at a single altitude. Another variable factor is weight. Fuel accounts for nearly 16 percent of the aircraft maximum gross weight, and on a long flight this could appreciably alter performance data. An option which utilizes fuel readings might well be a worthwhile addition.

Another section which might be added to the program is one which would plot rate of climb curves for the aircraft. This could be a simple subroutine which would require inputs of time to climb through a given altitude change over a range of velocities. An easy conversion to feet per minute could be made, and the results plotted.

Other future possibilities include the area of dynamic stability and control information, such as roll rates, which are covered in the second half of the flight evaluation techniques course sequence.

APPENDIX A
COMPUTER PROGRAM

```
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCSNA0010
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCSNA0020
C                                                                       CSNA0030
C     CESSNA                                                            CSNA0040
C                                                                       CSNA0050
C                                                                       CSNA0060
C     PURPOSE                                                           CSNA0070
C                                                                       CSNA0080
C        TO REDUCE RAW DATA FROM THE CESSNA 310H AIRCRAFT AND OUTPUT    CSNA0090
C        TABULAR AND GRAPHICAL INFORMATION FOR POWER VS. VELOCITY, AND  CSNA0100
C        LIFT VS. DRAG COEFFICIENTS.                                    CSNA0110
C                                                                       CSNA0120
C     METHOD                                                            CSNA0130
C                                                                       CSNA0140
C        STUDENT INPUTS TO THE PROGRAM ARE NUMBER OF ENGINES, FLIGHT    CSNA0150
C        ALTITUDE, TEMPERATURE, AIRCRAFT WEIGHT, RPM, MANIFOLD PRESSURE,CSNA0160
C        AND VELOCITY.  THE PROGRAM USES BUILT-IN TABULAR VALUES FROM   CSNA0170
C        THE ENGINE CURVES TO INTERPOLATE OR EXTRAPOLATE RPM AND MAP    CSNA0180
C        DATA, CALCULATES SEA LEVEL AND ALTITUDE VALUES OF BRAKE HORSE- CSNA0190
C        POWER, CORRECTS FOR NUMBER OF ENGINES, TEMPERATURE, AND PRO-   CSNA0200
C        PELLOR EFFICIENCY, AND REDUCES THE RESULT TO EQUIVALENT SHAFT  CSNA0210
C        HORSEPOWER, WHICH IS PLOTTED AGAINST EQUIVALENT VELOCITY.  LIFTCSNA0220
C        AND DRAG COEFFICIENTS ARE CALCULATED AS FUNCTIONS OF WEIGHT,   CSNA0230
C        VELOCITY, AND POWER REQUIRED, AND ARE PLOTTED ON A SECOND      CSNA0240
C        GRAPH.                                                         CSNA0250
C                                                                       CSNA0260
C        RPM MAY BE CONSTANT OR VARYING.  IF CONSTANT, SET THE FLAG     CSNA0270
C        (ONERPM) EQUAL TO "1" AND USE THE DECK FORMAT GIVEN BELOW FOR  CSNA0280
C        CONSTANT RPM.  IF RPM VARIES IN THE DATA, SET ONERPM EQUAL     CSNA0290
C        TO "0" AND USE THE VARIABLE RPM DECK FORMAT.                   CSNA0300
C                                                                       CSNA0310
C        FOR EASE IN LOADING THE DATA, ALL NUMBERS EXCEPT THE CONSTANT/ CSNA0320
C        VARIABLE RPM FLAG ARE REAL*4.  DATA LIMIT IS 100 POINTS.       CSNA0330
C        DATA MAY BE LOADED IN ANY ORDER (E.G., VELOCITY DOES NOT NEED  CSNA0340
C        TO BE IN INCREASING ORDER).                                    CSNA0350
C                                                                       CSNA0360
C                                                                       CSNA0370
C                                                                       CSNA0380
C                                                                       CSNA0390
C                  INPUT FORMAT FOR CESSNA (CONSTANT RPM)               CSNA0400
C                                                                       CSNA0410
C                                                                       CSNA0420
C     -----------------------------------------------------------------CSNA0420
C      CARD   | COLUMN |               DESCRIPTION              |FORMATCSNA0430
C     NUMBER  | NUMBER |                                        |      CSNA0440
C     --------|--------|----------------------------------------|------CSNA0450
C        1    |  1-10  | NOENG= NUMBER OF ENGINES (REAL*4)      | F10.3CSNA0460
C     --------|--------|----------------------------------------|------CSNA0470
C        2    |  1-10  | ALT= ALTITUDE (FEET)                   |8F10.3CSNA0480
```

```
C              |  11-20   | TEMPF= TEMPERATURE (DEGREES F)          |          CSNA0490
C                                                                              CSNA0500
C  -----3----- |---1-10---|-WT= AIRCRAFT WEIGHT (POUNDS)------------|---F10.3CSNA0510
C                                                                              CSNA0520
C  -----4----- |----1-----|-ONERPM= "1" (SIGNIFIES CONSTANT RPM)----|----I1  CSNA0530
C                                                                              CSNA0540
C  -----5----- |---1-10---|-POINTS= NO. OF DATA POINTS (REAL*4)-----|---F10.3CSNA0550
C                                                                              CSNA0560
C  -----6----- |---1-10---|-VEL(1)= VELOCITY (KNOTS)----------------|--8F10.3CSNA0570
C       .      |  11-20   | VEL(2)                                  |          CSNA0580
C       .      |   ETC.   |                                         |          CSNA0590
C                                                                              CSNA0600
C  6 + N78     |---1-10---|-MAP(1)= MANIFOLD PRESSURE (INCHES HG)---|--8F10.3CSNA0610
C       .      |  11-20   | MAP(2)                                  |          CSNA0620
C       .      |   ETC.   |                                         |          CSNA0630
C                                                                              CSNA0640
C  7 + N78     |---1-10---|-RPM= (CONSTANT)-------------------------|---F10.3CSNA0650
C                                                                              CSNA0660
C  ----------- |----------|-----------------------------------------|-------CSNA0670
C                                                                              CSNA0680
C                                                                              CSNA0690
C                                                                              CSNA0700
C                                                                              CSNA0710
C                                                                              CSNA0720
C                                                                              CSNA0730
C                                                                              CSNA0740
C                                                                              CSNA0750
C                                                                              CSNA0760
C               INPUT FORMAT FOR CESSNA (VARIABLE RPM)                         CSNA0770
C                                                                              CSNA0780
C  ------------------------------------------------------------------------CSNA0790
C     CARD     |  COLUMN  |               DESCRIPTION               |  FORMATCSNA0800
C    NUMBER    |  NUMBER  |                                         |          CSNA0810
C                                                                              CSNA0820
C  -----1----- |---1-10---|-NOENG= NUMBER OF ENGINES (REAL*4)-------|---F10.3CSNA0830
C                                                                              CSNA0840
C  -----2----- |---1-10---|-ALT= ALTITUDE (FEET)--------------------|--8F10.3CSNA0850
C              |  11-20   | TEMPF= TEMPERATURE (DEGREES F)          |          CSNA0860
C                                                                              CSNA0870
C  -----3----- |---1-10---|-WT= AIRCRAFT WEIGHT (POUNDS)------------|---F10.3CSNA0880
C                                                                              CSNA0890
C  -----4----- |----1-----|-ONERPM= "0" (SIGNIFIES VARIABLE RPM)----|----I1  CSNA0900
C                                                                              CSNA0910
C  -----5----- |---1-10---|-POINTS= NO. OF DATA POINTS (REAL*4)-----|---F10.3CSNA0920
C                                                                              CSNA0930
C  -----6----- |---1-10---|-VEL(1)= VELOCITY (KNOTS)----------------|--8F10.3CSNA0940
C       .      |  11-20   | VEL(2)                                  |          CSNA0950
C       .      |   ETC.   |                                         |          CSNA0960
```

```
C                                                                       CSNA0970
C      6 + N78  |  1-10   | MAP(I)= MANIFOLD PRESSURE (INCHES HG)  | 8F10.3CSNA0980
C         .     |  11-20  | MAP(2)                                 |      CSNA0990
C         .     |  ETC.   |                                        |      CSNA1000
C      ---------|---------|----------------------------------------|------CSNA1010
C      6 + N74  |  1-10   | RPM(1)                                 | 8F10.3CSNA1020
C         .     |  11-20  | RPM(2)                                 |      CSNA1030
C         .     |  ETC.   |                                        |      CSNA1040
C      ---------|---------|----------------------------------------|------CSNA1050
C                                                                       CSNA1060
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCSNA1070
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCSNA1080
      REAL*4 MAPSIG(100),LSLOPE,NOENG,SSLPWR(100),MAP(100),RA(16),RS(16)CSNA1090
      REAL*4 RSLOPE(100),MAXMAP(100),MAXBHP(100),ARSLOP(100),MABHP(100) CSNA1100
      REAL*4 VEL(100),RMAP(16),RSIG(16),PEFPPS(100),EQVEL(100)          CSNA1110
      REAL*4 RC(9,6),RPM(100),DUMMY,RC1(9),RC2(9)                       CSNA1120
      REAL*4 RC3(9),RC4(9),RC5(9),RC6(9)                                CSNA1130
      REAL*4 VEFPS(100),CLIFT(100),CDRAG(100),BHPALT(100)               CSNA1140
      INTEGER*4 ONERPM                                                  CSNA1150
      REAL*8 TITLE1(12),TITLE2(12)                                      CSNA1160
      INTEGER*4 ITB(12)                                                 CSNA1170
      REAL*4 RTB1(28)/28*0.0/,RTB2(28)/28*0.0/                          CSNA1180
      EQUIVALENCE (TITLE1,RTB1(5)),(TITLE2,RTB2(5))                     CSNA1190
      EQUIVALENCE (RC1(1),RC(1,1)),(RC2(1),RC(1,2)),(RC3(1),RC(1,3))    CSNA1200
      EQUIVALENCE (RC4(1),RC(1,4)),(RC5(1),RC(1,5)),(RC6(1),RC(1,6))    CSNA1210
      DATA ITB/0,5,8,10,0,0,1,1,0,1,0,1/                                CSNA1220
      DATA PE/.75/                                                      CSNA1230
      DATA S/200./                                                      CSNA1240
C                                                                       CSNA1250
C                                                                       CSNA1260
C     PART I - AIRCRAFT POWER REQUIREMENTS                              CSNA1270
C                                                                       CSNA1280
C                                                                       CSNA1290
C     LOAD PERMANENT ENGINE DATA FOR USE IN INTERPOLATION               CSNA1300
C                                                                       CSNA1310
      READ (5,10) RC                                                    CSNA1320
   10 FORMAT (9F8.3)                                                    CSNA1330
      READ (5,40) (RMAP(I),I=1,16)                                      CSNA1340
      READ (5,40) (RSIG(I),I=1,16)                                      CSNA1350
      READ (5,40) (RA(I),I=1,16)                                        CSNA1360
      READ (5,20) (RS(I),I=1,16)                                        CSNA1370
   20 FORMAT (8F10.5)                                                   CSNA1380
C                                                                       CSNA1390
C     LOAD TITLES FOR GRAPHICAL OUTPUT                                  CSNA1400
C                                                                       CSNA1410
      READ (5,30) TITLE1                                                CSNA1420
      READ (5,30) TITLE2                                                CSNA1430
   30 FORMAT (6A8)                                                      CSNA1440
```

```
C
C     INPUT NUMBER OF ENGINES
C
      READ (5,40) NOENG
   40 FORMAT (3F10.3)
C
C     INPUT FLIGHT ALTITUDE AND TEMPERATURE (DEGREES F)
C
      READ (5,40) ALT,TEMPF
C
C     INPUT WEIGHT
C
      READ (5,40) WT
C
C     INPUT CONSTANT/VARIABLE RPM FLAG
C
      READ (5,50) ONERPM
   50 FORMAT (I1)
C
C     INPUT VELOCITY, MANIFOLD PRESSURE, AND RPM
C
      READ (5,40) POINTS
      IPTS = POINTS
      READ (5,40) (VEL(I),I=1,IPTS)
      READ (5,40) (MAP(I),I=1,IPTS)
      IF(ONERPM.EQ.1) GO TO 60
      READ (5,40) (RPM(I),I=1,IPTS)
      GO TO 70
   60 READ(5,40) RPM(1)
      DO 70 I=2,IPTS
      RPM(I) = RPM(1)
   70 CONTINUE
      CALL SORT(IPTS,VEL,MAP,RPM)
      IF(ONERPM.EQ.0) GO TO 80
      I=1
      GO TO 90
   80 DO 100 I=1,IPTS
   90 CALL LINT(RC1,RC2,9,RPM(I),DUMMY)
      RSLOPE(I) = DUMMY
      CALL LINT (RC1,RC3,9,RPM(I),DUMMY)
      MAXMAP(I) = DUMMY
      CALL LINT (RC1,RC4,9,RPM(I),DUMMY)
      MAXBHP(I) = DUMMY
      CALL LINT (RC1,RC5,9,RPM(I),DUMMY)
      ARSLOP(I) = DUMMY
      CALL LINT (RC1,RC6,9,RPM(I),DUMMY)
      MABHP(I) = DUMMY
  100 CONTINUE
```

```
      DO 110 I=1,IPTS
      CALL LINT (RMAP,RSIG,16,MAP(I),DUMMY)
      MAPSIG(I) = DUMMY
  110 CONTINUE
C
      CALL LINT (RA,RS,16,ALT,SIGMA)
      WRITE (6,120)
  120 FORMAT (/////)
      WRITE (6,120)
      WRITE (6,130)
  130 FORMAT (' ','PROGRAM OUTPUT - DATA LISTING'/////)
      IALT = ALT
      WRITE (6,140) IALT
  140 FORMAT (' ','FLIGHT ALTITUDE IS ',I5,' FEET'//)
      WRITE (6,150) SIGMA
  150 FORMAT (' ','SIGMA = ',F9.5//)
      IWT = WT
      WRITE (6,160) IWT
  160 FORMAT (' ','AIRCRAFT WEIGHT IS ',I4,' POUNDS'//)
      WRITE (6,170) TEMPF
  170 FORMAT (' ','TEMPERATURE AT ALTITUDE IS ',F6.2,' DEGREES FAHRENHEI
     1T'//)
C
C     CHANGE DEGREES F TO DEGREES C
C
      DEGC = 5.*(TEMPF-32.)/9.
C
C     GET DIFFERENCE FROM STANDARD TEMPERATURE
C
      TDIF = 15.-DEGC
      I = 1
      DO 200 J=1,IPTS
      IF (ONERPM.EQ.0) I = J
C
C     GET SEA LEVEL BHP
C
      SSLBHP = MAXBHP(I)-RSLOPE(I)*(MAXMAP(I)-MAP(J))
C
C     GET CRITICAL BHP FOR GIVEN ALTITUDE AND MAP
C
      BHPCR = MABHP(I)-ARSLOP(I)*(1.-MAPSIG(J))
C
C     GET SLOPE OF LINE CONNECTING SEA LEVEL BHP AND CRITICAL BHP
C
      LSLOPE = (BHPCR-SSLBHP)/(1.-MAPSIG(J))
C
C     GET BHP AT GIVEN ALTITUDE
C
```

```
      IF (SIGMA.LT.MAPSIG(J)) GO TO 180                                 CSNA2410
      BHPALT(J) = SSLBHP+LSLOPE*(1.-SIGMA)                              CSNA2420
      GO TO 190                                                         CSNA2430
  180 BHPALT(J) = MABHP(I)-ARSLOP(I)*(1.-SIGMA)                         CSNA2440
C                                                                       CSNA2450
C     CORRECT FOR TEMPERATURE                                           CSNA2460
C                                                                       CSNA2470
  190 CBHP = BHPALT(J)*(1.+(1.666667E-03*TDIF))                         CSNA2480
C                                                                       CSNA2490
C     CORRECT FOR NUMBER OF ENGINES                                     CSNA2500
C                                                                       CSNA2510
      TBHPA = CBHP*NOENG                                                CSNA2520
C                                                                       CSNA2530
C     CORRECT FOR PROPELLER EFFICIENCY                                  CSNA2540
C                                                                       CSNA2550
      TSHPA = TBHPA/PE                                                  CSNA2560
C                                                                       CSNA2570
C     CHANGE TO EQUIVALENT POWER                                        CSNA2580
C                                                                       CSNA2590
      SSLPWR(J) = TSHPA*SQRT(SIGMA)                                     CSNA2600
  200 CONTINUE                                                          CSNA2610
      DO 210 I=1,IPTS                                                   CSNA2620
  210 EQVEL(I) = VEL(I)*SQRT(SIGMA)                                     CSNA2630
C                                                                       CSNA2640
C                                                                       CSNA2650
C                                                                       CSNA2660
C     PART II - LIFT VS. DRAG                                           CSNA2670
C                                                                       CSNA2680
C                                                                       CSNA2690
      C1 = 6000./3600.                                                  CSNA2700
      C3 = 2./(.0023769*S)                                              CSNA2710
      C2 = C3*WT                                                        CSNA2720
      DO 220 I=1,IPTS                                                   CSNA2730
C                                                                       CSNA2740
C     CHANGE VELOCITY FROM KNOTS TO FEET PER SECOND                     CSNA2750
C                                                                       CSNA2760
      VEFPS(I) = EQVEL(I)*C1                                            CSNA2770
C                                                                       CSNA2780
C     FIND LIFT COEFFICIENT AS FCN OF WT AND EQUIV VELOCITY             CSNA2790
C                                                                       CSNA2800
      CLIFT(I) = C2/VEFPS(I)**2                                         CSNA2810
C                                                                       CSNA2820
C     CHANGE EQUIV PWR FROM SHP TO FT-LBS/SEC                           CSNA2830
C                                                                       CSNA2840
      PEFPPS(I) = SSLPWR(I)*550.                                        CSNA2850
C                                                                       CSNA2860
C     FIND DRAG COEFFICIENT AS FCN OF EQUIV PWR REQD AND EQUIV VELOCITY CSNA2870
C                                                                       CSNA2880
```

```
220 CDRAG(I) = C3*PEFPPS(I)/VEFPS(I)**3
    WRITE (6,120)
    DO 230 I=1,IPTS
    WRITE (6,240) I,VEL(I),RPM(I),MAP(I),BHPALT(I),EQVEL(I),SSLPWR(I),
   1CLIFT(I),CDRAG(I)
230 CONTINUE
240 FORMAT (1X,I2,5X,F6.1,5X,F6.0,5X,F5.1,5X,F6.1,5X,F6.1,5X,F6.1,5X,F
   16.3,5X,F6.3/)
    WRITE (6,250)
250 FORMAT (' ',1X,'I',6X,'VEL(I)',5X,'RPM(I)',4X,'MAP(I)',4X,'BHPALT(
   1I)',2X,'EQVEL(I)',2X,'SSLPWR(I)',2X,'CLIFT(I)',4X,'CDRAG(I)'///)
    WRITE (6,260)
260 FORMAT (//' ','WHERE'//' ','VEL = VELOCITY (KNOTS)'/' ','MAP = MAN
   1IFOLD PRESSURE (INCHES HG)'/' ','BHPALT = THRUST HORSEPOWER (SINGL
   2E ENGINE) AT ALTITUDE'/' ','EQVEL = SEA LEVEL EQUIVALENT VELOCITY
   3(KNOTS)'/' ','SSLPWR = SEA LEVEL EQUIVALENT A/C SHAFT HORSEPOWER'/
   4' ','CLIFT = COEFFICIENT OF LIFT'/' ','CDRAG = COEFFICIENT OF DRAG
   5'/////)
    CALL DRAWP (IPTS,EQVEL,SSLPWR,ITB,RTB1)
    CALL DRAWP (IPTS,CDRAG,CLIFT,ITB,RTB2)
    STOP
    END
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCC
C
C      SUBROUTINE LINT
C
C
C      PURPOSE
C
C         TO PERFORM A LINEAR INTERPOLATION/EXTRAPOLATION OF DATA ENTERED
C         IN TWO COLUMNS, WHERE VALUES OF THE INDEPENDENT VARIABLE MUST
C         BE DISTINCT AND IN MONOTONICALLY INCREASING ORDER BUT MAY BE
C         ARBITRARILY SPACED.
C
C      CALLING SEQUENCE
C
C         CALL LINT(X,Y,M,XINT,YINT)
C
C      DESCRIPTION OF ARGUMENTS
C
C         X    - VECTOR OF INDEPENDENT VARIABLES (REAL*4).
C
C         Y    - VECTOR OF DEPENDENT VARIABLES (REAL*4).
C
C         M    - DIMENSION OF VECTORS X AND Y (INTEGER*4).
C
C         XINT- VALUE OF THE INDEPENDENT VARIABLE FOR WHICH THE DEPENDENT
C               VARIABLE IS TO BE INTERPOLATED/EXTRAPOLATED (REAL*4).
```

```
C                                                                       CSNA3370
C         YINT- VALUE OF THE DEPENDENT VARIABLE (INTERPOLATED) WHICH IS CSNA3380
C               RETURNED TO THE CALLING PROGRAM (REAL*4).               CSNA3390
C                                                                       CSNA3400
C      COMMENTS                                                         CSNA3410
C                                                                       CSNA3420
C         THE PROGRAM EXTRAPOLATES ONLY IF THE VALUE OF XINT IS LESS THANCSNA3430
C         THE LOWEST VALUE OF X.  IF XINT IS GREATER THAN THE LARGEST   CSNA3440
C         VALUE OF X, AN ERROR MESSAGE IS PRINTED OUT.                  CSNA3450
C                                                                       CSNA3460
C                                                                       CSNA3470
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCSNA3480
      SUBROUTINE LINT(X,Y,M,XINT,YINT)                                  CSNA3490
      DIMENSION X(M),Y(M)                                               CSNA3500
      IF((X(1)-XINT).GT.0.05) GO TO 30                                  CSNA3510
      DO 10 I=1,M                                                       CSNA3520
      IF((XINT-X(I)).LE.0.05) GO TO 40                                  CSNA3530
      J=I+1                                                             CSNA3540
      IF((X(J)-XINT).GT.0.05) GO TO 50                                  CSNA3550
   10 CONTINUE                                                          CSNA3560
      WRITE(6,20)                                                       CSNA3570
   20 FORMAT(//' ','INDEPENDENT VARIABLE ABOVE RANGE FOR INTERPOLATION')CSNA3580
      RETURN                                                            CSNA3590
   30 RK=(X(1)-XINT)/(X(2)-X(1))                                        CSNA3600
      YINT=Y(1)-RK*(Y(2)-Y(1))                                          CSNA3610
      RETURN                                                            CSNA3620
   40 YINT=Y(I)                                                         CSNA3630
      RETURN                                                            CSNA3640
   50 RK=(XINT-X(I))/(X(J)-X(I))                                        CSNA3650
      YINT=Y(I)+RK*(Y(J)-Y(I))                                          CSNA3660
      RETURN                                                            CSNA3670
      END                                                               CSNA3680
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCSNA3690
C                                                                       CSNA3700
C      SUBROUTINE SORT                                                  CSNA3710
C                                                                       CSNA3720
C      PURPOSE                                                          CSNA3730
C                                                                       CSNA3740
C         TO SORT A COLUMN OF DATA AND PUT IT IN INCREASING ORDER OF    CSNA3750
C         VALUES, AND TO PUT TWO ASSOCIATED COLUMNS OF DATA IN THE      CSNA3760
C         SAME ORDER.                                                   CSNA3770
C                                                                       CSNA3780
C      CALLING SEQUENCE                                                 CSNA3790
C                                                                       CSNA3800
C         CALL SORT(N,V,V1,V2)                                          CSNA3810
C                                                                       CSNA3820
C      DESCRIPTION OF ARGUMENTS                                         CSNA3830
C                                                                       CSNA3840
```

```
C          N - DIMENSION OF VECTORS V, V1, AND V2.  N.LE.100                 CSNA3850
C                                                                            CSNA3860
C          V - INDEPENDENT DATA TO BE SORTED (REAL*4)                        CSNA3870
C                                                                            CSNA3880
C          V1,V2 - DEPENDENT DATA TO BE SORTED IN SAME ORDER AS V (REAL*4)CSNA3890
C                                                                            CSNA3900
C                                                                            CSNA3910
CCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCCSNA3920
      SUBROUTINE SORT(N,V,V1,V2)                                             CSNA3930
      LOGICAL TEST                                                           CSNA3940
      REAL*4 V(N),V1(N),V2(N)                                                CSNA3950
      REAL*4 VX(100,3)                                                       CSNA3960
      DO 10 I=1,N                                                            CSNA3970
      VX(I,1)=V(I)                                                           CSNA3980
      VX(I,2)=V1(I)                                                          CSNA3990
   10 VX(I,3)=V2(I)                                                          CSNA4000
   20 TEST = .FALSE.                                                         CSNA4010
      DO 30 I=2,N                                                            CSNA4020
      IF(VX(I,1).GE.VX(I-1,1)) GO TO 30                                      CSNA4030
      TEST = .TRUE.                                                          CSNA4040
      DO 30 J=1,3                                                            CSNA4050
      STORE=VX(I,J)                                                          CSNA4060
      VX(I,J)=VX(I-1,J)                                                      CSNA4070
      VX(I-1,J)=STORE                                                        CSNA4080
   30 CONTINUE                                                               CSNA4090
      IF(TEST) GO TO 20                                                      CSNA4100
      DO 40 I=1,N                                                            CSNA4110
      V(I)=VX(I,1)                                                           CSNA4120
      V1(I)=VX(I,2)                                                          CSNA4130
   40 V2(I)=VX(I,3)                                                          CSNA4140
      RETURN                                                                 CSNA4150
      END                                                                    CSNA4160
C     NOTE.../* IS REMOVED HERE FOR PRINTING PURPOSES
//GO.SYSIN DD *
1800.    1900.    2000.    2100.    2200.    2300.    2400.    2500.    2625.
6.45     7.16     7.37     8.17     8.72     9.24     10.00    10.56    11.09
29.75    29.70    29.65    29.60    29.55    29.50    29.40    29.40    29.35
150.0    164.5    175.0    193.0    208.5    223.5    239.0    248.0    260.0
173.913  186.667  200.000  216.667  235.165  254.945  267.033  281.319  294.505
150.0    163.0    175.0    191.0    207.5    223.5    237.5    249.0    260.0
14.         15.         16.         17.         18.         19.         20.         21.
22.         23.         24.         25.         26.         27.         28.         29.
.545        .58         .615        .64         .675        .705        .73         .76
.79         .82         .855        .88         .905        .935        .965        .99
0.0         1000.       2000.       3000.       4000.       5000.       6000.       7000.
8000.       9000.       10000.      11000.      12000.      13000.      14000.      15000.
1.0         .97106      .94277      .91512      .88808      .86167      .83586      .81064
.78601      .76196      .73848      .71555      .69317      .67133      .65002      .62923
```

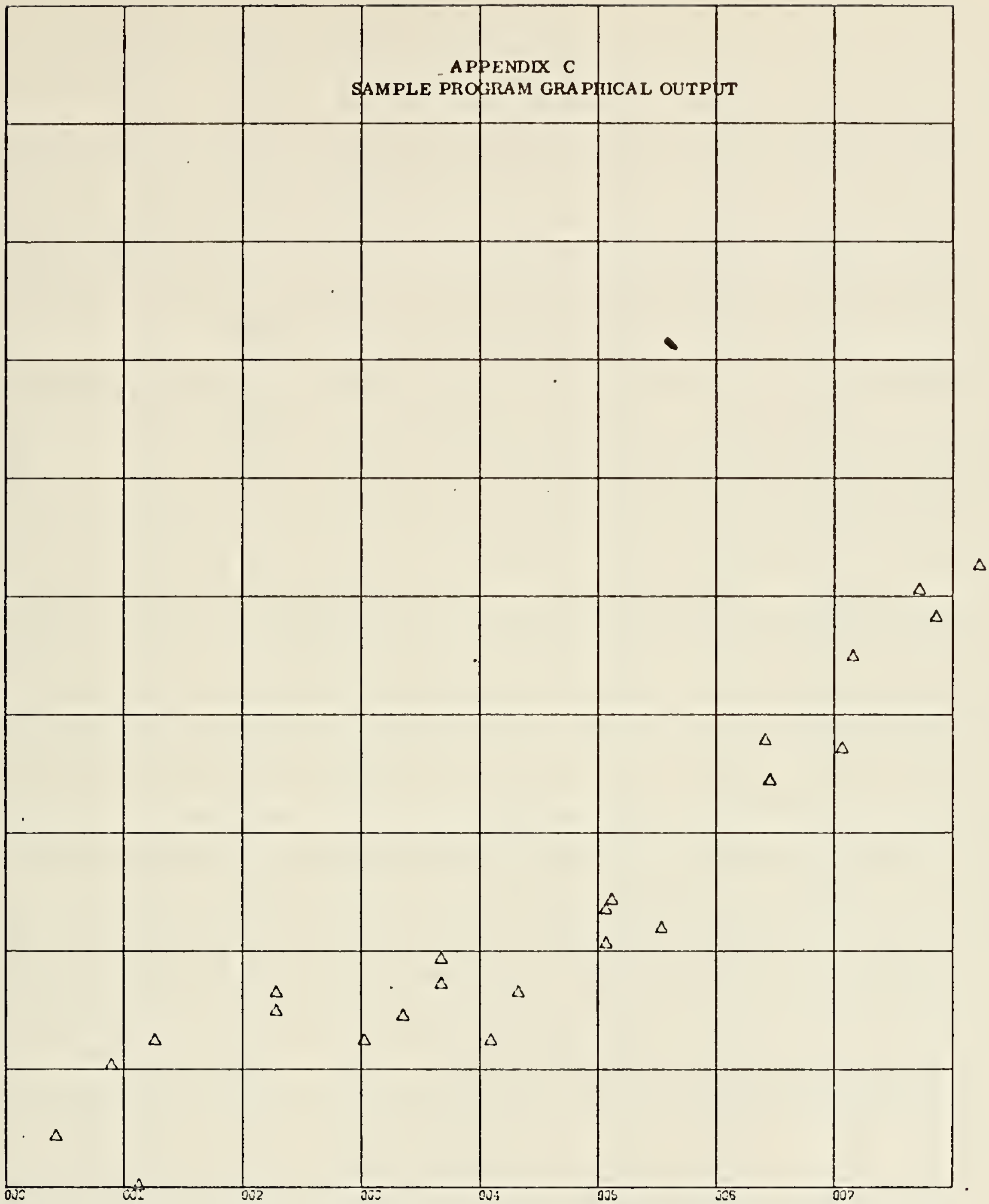
EQUIVALENT POWER REQUIRED (SHP)
VS. AIRSPEED (KNOTS) - CESSNA 310H
LIFT COEFF. VS. DRAG COEFF.
CESSNA 310H

APPENDIX B

SAMPLE INPUT DATA DECK

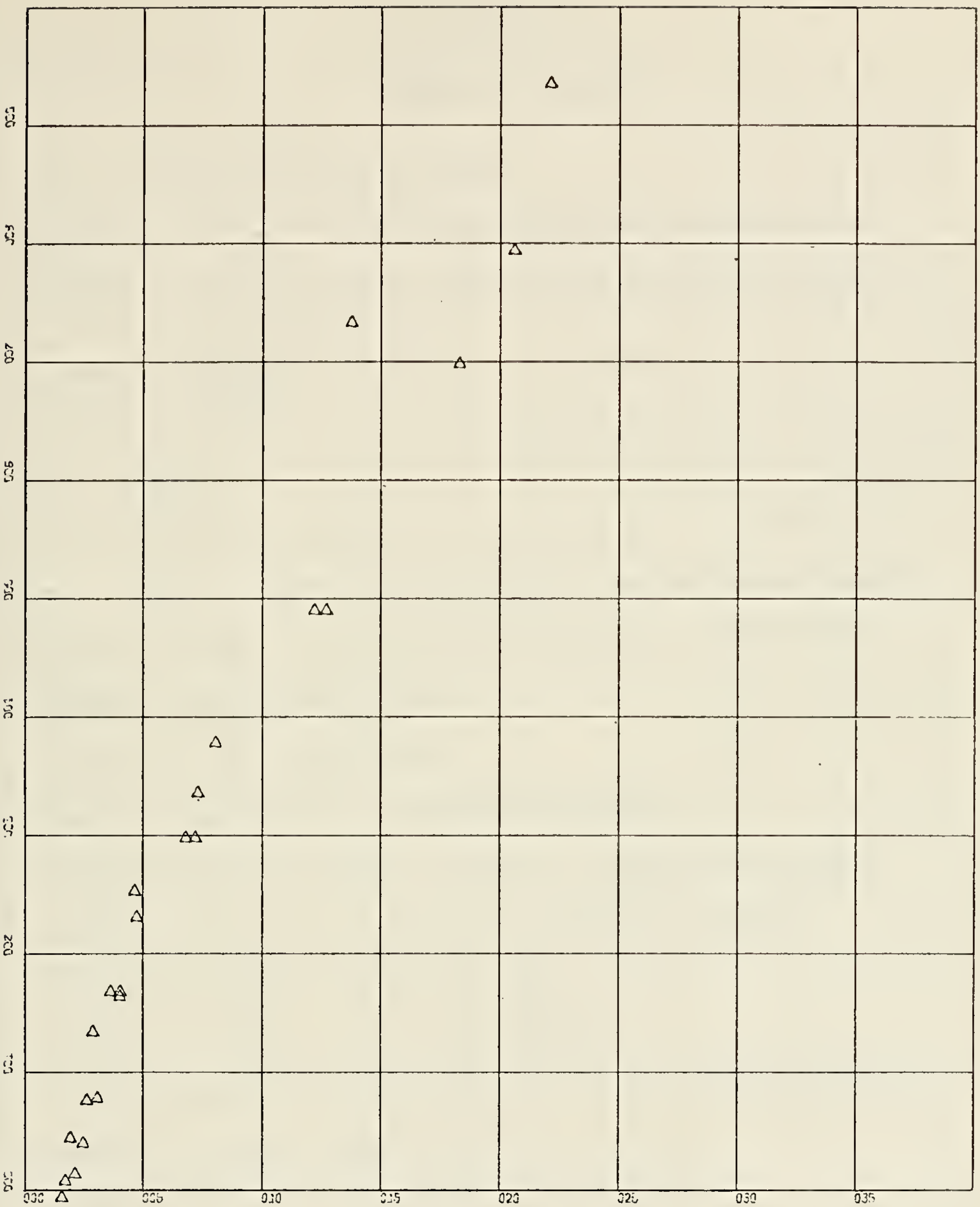
2.							
5000.	76.55						
4500.							
0							
26.							
85.	100.	115.	130.	145.	160.	160.	145.
130.	115.	100.	85.	164.	151.5	135.	119.5
108.	87.5	80.	89.	111.5	122.	130.5	144.5
152.5	158.5						
17.5	19.	19.75	20.8	22.0	23.6	23.6	22.0
20.1	19.2	18.6	17.5	23.	20.	18.	18.
18.	15.	16.	18.	18.5	19.	21.	21.5
23.	24.						
2100.	2100.	2100.	2100.	2200.	2300.	2300.	2200.
2100.	2100.	2100.	2100.	2450.	2450.	2300.	2100.
2100.	2100.	2100.	2100.	2100.	2100.	2100.	2300.
2300.	2300.						

APPENDIX C
SAMPLE PROGRAM GRAPHICAL OUTPUT



X-SCALE=1.00E+01 UNITS INCH.   ADD +7.00E+01 UNITS TO ALL X VALUES.
Y-SCALE=5.00E+01 UNITS INCH.   ADD +2.00E+02 UNITS TO ALL Y VALUES.

EQUIVALENT POWER REQUIRED (SHP)
VS. AIRSPEED (KNOTS) - CESSNA 310H



X-SCALE=5.00E-02 UNITS INCH.   ADD +5.00E-02 UNITS TO ALL X VALUES.
Y-SCALE=1.00E-01 UNITS INCH.   ADD +3.00E-01 UNITS TO ALL Y VALUES.

LIFT COEFF. VS. DRAG COEFF.
CESSNA 310H

APPENDIX D

PROGRAM GLOSSARY

ALT - (input) Altitude (feet)

ARSLOP - Slope of any altitude performance RPM line

BHPALT - Single engine uncorrected thrust horsepower at altitude

BHPCR - Critical horsepower at altitude for any given RPM and MAP

C1 - Conversion factor for changing velocity to feet per second

C2 - Constant for use in determining drag coefficient

C3 - Constant for use in determining lift coefficient

CBHP - BHPALT corrected for temperature variation

CDRAG - Drag coefficient

CLIFT - Lift coefficient

DEGC - Temperature, degrees Centigrade

DUMMY - Dummy variable used for temporary storage

EQVEL - Sea level equivalent velocity (knots)

IALT - Integer version of ALT

IPTS - Integer version of POINTS

ITB - Vector of constants for use in DRAWP subroutine

IWT - Integer version of WT

LINT - Linear interpolation subroutine

LSLOPE - Slope of the line connecting sea level and altitude values of BHP (SSLBHP and BHPCR) for any given RPM and MAP

MABHP - Maximum horsepower for any given altitude performance RPM line

MAP - (input) Manifold pressure (inches Hg)

MAPSIG - Performance curve equivalent value of density ratio for any given value of MAP

MAXBHP - Maximum horsepower for any given sea level performance RPM line

MAXMAP - Maximum manifold pressure for any given sea level performance RPM line

NOENG - (input) Number of engines operating

ONERPM - (input) Constant/variable RPM flag

PE - Propeller efficiency

PEFPPS - Sea level equivalent power (foot pounds per second)

POINTS - (input) Number of data points

RA - Vector of altitudes used for converting altitude to density ratio

RC - Matrix of engine performance curve data

RC1-RC6 - Vector equivalents of data contained in RC

RMAP - Vector of manifold pressures used for MAPSIG conversion

RPM - (input) Engine revolutions per minute

RS - Vector of density ratios used for converting altitude to density ratio

RSIG - Vector of density ratios used for MAPSIG conversion

RSLOPE - Slope of any sea level performance RPM line

RTB1 - Vector of data used in DRAWP subroutine

RTB2 - Vector of data used in DRAWP subroutine

S - Aircraft characteristic area (square feet)

SIGMA - Density ratio for a given altitude

SORT - Sorting subroutine

SSLBHP - Sea level power for any given RPM and MAP

SSLPWR - Sea level equivalent total shaft horsepower

TBHPA - Total horsepower at altitude corrected for temperature and number of engines

TDIF - Difference between standard temperature and temperature at flight altitude

TEMPF - (input) Temperature at altitude (degrees Fahrenheit)

TITLE1 - Graph title information for DRAWP subroutine

TITLE2 - Graph title information for DRAWP subroutine

TSHPA - TBHPA corrected for propeller efficiency

VEFPS - Sea level equivalent velocity (feet per second)

VEL - (input) Velocity (knots)

WT - (input) Aircraft weight (pounds)

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